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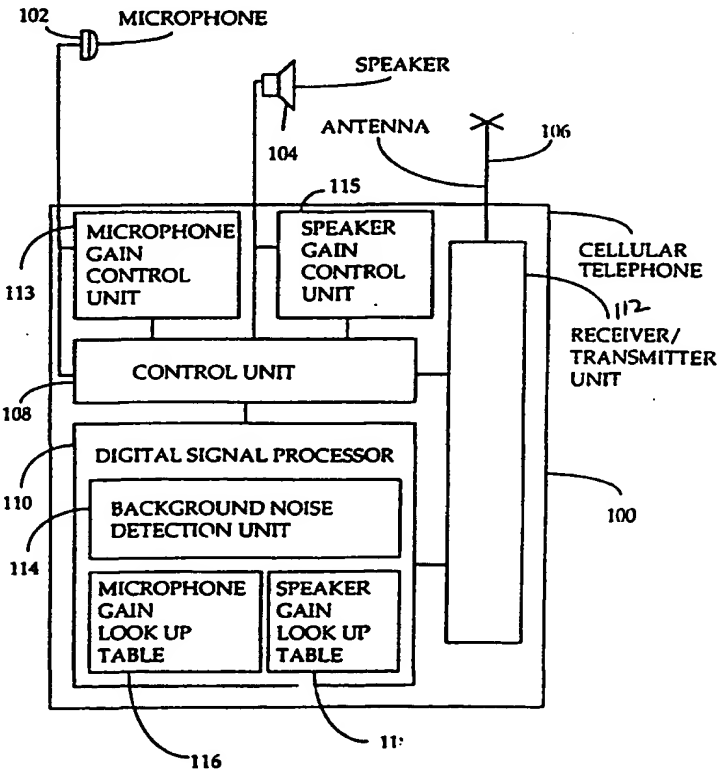
(54) Title: METHOD AND APPARATUS FOR AUTOMATICALLY ADJUSTING SPEAKER AND MICROPHONE GAINS WITHIN A MOBILE TELEPHONE

(57) **Abstract**

The cellular telephone (100) is provided with the capability for automatically adjusting the gain of a microphone (102) based upon the detected noise level in which the cellular telephone (100) is operated. As the noise level increases, the gain of the microphone (102) is automatically decreased thereby compensating for the natural tendency of telephone users to speak more loudly in noisy environments. Also, by decreasing the microphone gain, any clipping that might otherwise occur as a result to the user speaking more loudly is avoided and the signal to noise ratio is not thereby decreased. Furthermore, because the microphone gain decreases, the volume level of the voice of the user as it is output from the other party's telephone is not unduly loud. Hence, the other party need not manually decrease the speaker gain of his or her telephone. In the exemplary embodiment, the cellular telephone (100) includes a digital signal processor (110) configured or programmed to apply the detected noise level to look-up tables (116, 118) relating various noise levels to appropriate speaker and microphone gain levels. Also, in the exemplary embodiment, the mobile telephone includes a speaker (104) and the gain of the speaker is adjusted to increase in response to an increase in the background noise level.



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METHOD AND APPARATUS FOR AUTOMATICALLY ADJUSTING SPEAKER AND MICROPHONE GAINS WITHIN A MOBILE TELEPHONE

BACKGROUND OF THE INVENTION

I. Field of the Invention

The invention generally relates to mobile telephones and in particular to the audio microphone and speaker of a mobile telephone.

II. Description of the Related Art

Cellular telephones and other mobile telephones are commonly employed within a wide range of differing noise environments. For example, a cellular telephone may be employed within a relatively quiet office or home environment or within a relatively noisy manufacturing or traffic environment.

In a noisy environment, a user tends to speak more loudly into the microphone of the cellular telephone than in relatively quiet environments. This is a natural tendency arising from the assumption by the user that he or she must speak more loudly to be heard over the noise. Yet, such is often not necessary and, indeed, may be counterproductive. The microphone of the cellular telephone may be highly directional and therefore will not detect and amplify all of the noise that the user hears. Hence, it is unnecessary for the user to speak more loudly. Moreover, the cellular telephone may be capable of processing only a limited dynamic range of sound levels such that the voice of the user becomes clipped if the user speaks too loudly into the microphone. Such clipping can result in a decrease in the signal to noise ratio between the transmitted voice and the transmitted background noise level. Hence, by speaking loudly into the microphone, it may actually become more difficult for the listener to distinguish the voice of the user.

The clipping phenomenon described above is illustrated in **FIGS. 1** and **2**. More specifically, **FIG. 1** illustrates a voice signal **10** and a background noise signal **12** input to a cellular telephone. The background noise level increases beginning at time **14**. In response thereto, the user speaks more loudly resulting in an increase in the input voice signal level. As the noise level continues to rise, the user speaks even more loudly until reaching a point **16** where clipping begins. Thereafter, the voice is clipped yielding a

lower signal to noise ratio, as well as, a possibly distorted voice signal. FIG. 2 illustrates the resulting changes in the signal to noise ratio. As can be seen, the signal to noise ratio decreases following time 16.

Hence, in circumstances where clipping occurs, a user who tries to speak more loudly can actually reduce intelligibility. Even if clipping does not occur, the user speaking more loudly may cause annoyance to the listener, perhaps resulting in a need for the listener to decrease the volume of the speaker of his or her telephone. For many telephones, particularly non-mobile telephones, the volume of the speaker cannot be adjusted and hence the listener may not be able to achieve a comfortable volume level. Moreover, privacy may be jeopardized at the listener's end, if the voice of the user is too loud and the listener cannot decrease the speaker volume level.

Another problem arising from high noise levels is that it may be difficult for the user in the noisy environment to hear the voice of the other party. For many cellular telephones, the volume or gain of the speaker of the telephone can be manually increased to compensate, but such manual action by the user is inconvenient. Moreover, manual action may be dangerous, particularly if the user is driving in traffic while attempting to manually decrease the speaker gain.

Accordingly, there is a need to remedy the forgoing problems, and it is to that end that the invention is primarily drawn.

SUMMARY OF THE INVENTION

The forgoing problems are addressed by providing a cellular telephone, or other mobile telephone, with a means for adjusting the gain of a microphone of the telephone based upon the detected noise level in which the cellular telephone in operated. As the noise level increases, the gain of the microphone is automatically decreased thereby compensating for the tendency of telephone users to speak more loudly in noisy environments. Also, by decreasing the microphone gain, any clipping that might otherwise occur as a result of the user speaking more loudly is avoided and the signal to noise ratio is thereby not decreased. Furthermore, because the microphone gain decreases, the volume level of the voice of the user as it is output from the telephone of the other party to the telephone call is not unduly loud. Hence, the other party need not manually decrease the speaker gain of his or her telephone.

In an exemplary embodiment, automatic microphone gain adjustment is achieved by providing the cellular telephone with a means for detecting the background noise level of the environment in which the mobile telephone is operating and a means for setting the gain of a microphone of the mobile telephone based upon the detected background noise levels. The means for setting the gain of the microphone operates to decrease the gain in response to an increase in background noise by an amount inversely proportional to the background noise level. In the exemplary embodiment, the microphone gain is reduced by half the value of the increase in background noise measured in decibels.

In the exemplary embodiment, the mobile telephone further includes a means for automatically setting the gain of a speaker of the mobile telephone based upon the background noise level. More specifically, the means for setting the gain of the speaker operates to increase the gain in response to an increase in the background noise level. Hence, the user need not manually increase the speaker gain if the background noise level increases.

The invention is particularly well suited for use in cellular telephones employing digital signal processing (DSP) units. Many such cellular telephones include hardware or software within the DSP for calculating the background noise level from the input signal for the purposes of performing noise reduction. An exemplary embodiment for calculating the background noise level is described in detail in U.S. Patent No. 5,414,796, entitled "Variable Rate Vocoder", which is assigned to the assignee of the present invention and incorporated by reference herein. With such cellular telephones, the DSP is merely reconfigured or reprogrammed to apply the detected noise level to look-up tables relating various noise levels to appropriate speaker and microphone gain levels. A wide variety of other implementations are also possible.

Thus, with the invention, the above-described problems occurring when cellular telephones or other mobile telephones are used in environments having high background noise levels are substantially overcome. Other advantages of the invention, as well as other features and objects of the invention, will be apparent from the detailed description which follows and from the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a graph illustrating background noise levels and corresponding input voice levels for a cellular telephone operating in a changing noise environment;

FIG. 2 is a graph illustrating the signal to noise level for the input voice and noise signals of **FIG. 1**;

FIG. 3 is a block diagram of a cellular telephone configured in accordance with a preferred embodiment of the invention;

FIG. 4 is a block diagram of a microphone gain look-up table of the cellular telephone of **FIG. 3**; and

FIG. 5 is a block diagram of a speaker gain look-up table of the cellular telephone of **FIG. 3**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to the remaining figures, exemplary embodiments of the invention will now be described. The exemplary embodiments will primarily be described with reference to block diagrams illustrating apparatus elements. Depending upon the implementation, each apparatus element, or portions thereof, may be configured in hardware, software, firmware or combinations thereof. It should be appreciated that not all components necessary for a complete implementation of a practical system are illustrated or described in detail. Rather, only those components necessary for a thorough understanding of the invention are illustrated and described.

FIG. 3 illustrates a cellular telephone **100** having a microphone **102**, a speaker **104** and an antenna **106**. Pertinent internal components of the telephone illustrated in **FIG. 2** include a control unit **108**, a Digital Signal Processor (DSP) **110**, and a receiver/transmitter unit **112**. Also, included is a microphone gain control unit **113** and a speaker gain control unit **115**.

In use, a user of cellular telephone **100** speaks into microphone **102** and his or her voice and any detected background noise are routed by control unit **108** into DSP **110** for processing therein. In the exemplary embodiment,

the processed voice signals are encoded, by units not separately shown, using the cellular transmission protocol of Code Division Multiple Access (CDMA) as described in detail in the Telecommunication Industry Association's TIA/EIA/IS-95-A Mobile Station-Base Station Capability Standard for Dual-Mode Wideband Spread Spectrum Cellular System. The encoded signals are routed to receiver/transmitter **112**, then transmitted via antenna **106** to a local base station (not shown.) The signals may be forwarded from there to a remote telephone which may be another cellular telephone, other mobile phone or a land-line connected to a Public Switched Telephone Network (PSTN) (not shown). Voice signals transmitted to cellular phone **100** are received via antenna **106** and receiver/transmitter **112**, processed by DSP **110** and output through the speaker all under the control of the control unit **108**.

The DSP **110** may, depending upon the implementation, perform any of a variety of conventional digital processing functions on the voice signals. Additionally, DSP **110** determines the background noise level of the local environment from the signals detected by microphone **102** and sets the gain of microphone **102** to a level selected to compensate for the natural tendency of the user of cellular telephone **100** to speak more loudly in noisy environments. In the exemplary embodiment, the microphone gain is set to a level that is generally inversely proportional to the background noise level. In the exemplary embodiment, the microphone gain is decreased by half the increase in background noise measured in decibels.

To this end, DSP **110** includes background noise level detection unit **114**, microphone gain look-up table **116** and speaker gain look-up table **118**. Background noise level detector **114** determines, in accordance with conventional techniques, the background noise level from signals received from microphone **102**, yielding a digital value representative of the background noise level. The digital value may, for example, represent the background noise energy in decibels. DSP **110** applies the digital value to microphone gain look-up table **116** to read out a microphone gain value for applying to microphone **102** via microphone gain control unit **113**.

In the exemplary embodiment, the background noise level B' is determined in the current frame based on the previous frame background noise level B and the current frame energy E_f. In determining the new background noise level B' for use during the next frame (as the previous frame background noise estimate B) two values are computed. The first value V_1 is simply the current frame energy E_f. The second value V_2 is the

larger of B+1 and K*B, where K=1.00547. The smaller of the two values V_1 or V_2 is chosen as the new background noise level B'.

Mathematically,

$$V_1 = R(0) \quad (1)$$

$$V_2 = \min (160000, \max (K*B, B+1)) \quad (2)$$

and the new background noise level B' is:

$$B' = \min (V_1, V_2) \quad (3)$$

where min (x,y) is the minimum of x and y, and max (x,y) is the maximum of x and y.

FIG. 4 illustrates an exemplary microphone gain look-up table having entries 120 for various background noise levels and entries 122 for corresponding microphone gain values. The microphone gain values may, for example, be digital representations of voltage or current levels for applying to an amplifier of microphone 102 (not shown). Entries 120 may specify individual noise levels or ranges of noise levels. Every expected quantized input noise level is represented within the look-up table 116. If a noise level is detected that does not have a corresponding entry in the table, a default value is employed. In accordance with conventional techniques, look-up table 116 may be implemented as a portion of read only memory (ROM). In other implementations, look up table 116 may be implemented using other appropriate techniques, such as a software algorithms.

As noted, the background noise level value read out from microphone gain look-up table 116 is applied to microphone 102 to adjust its gain. By storing values in look-up table 116 that provide a microphone gain that is decreased with increasing noise levels, the natural tendency of a telephone user to speak more loudly in a noisy environment is automatically compensated. Also, by decreasing the microphone gain, a loss in signal to noise ratio caused by signal clipping, in microphone 102 itself or in DSP 110, is avoided.

The background noise levels may be calculated and corresponding gain levels read out and applied to microphone 102 either continuously or periodically. In the exemplary embodiment, the microphone gain is readjusted every two or three seconds, thereby accommodating for the typical delay between an increase in the background noise level and a corresponding increase in the loudness of the voice of the user. In an

alternative embodiment, the noise level is detected and the gain set only once per call or perhaps only at power-up of the cellular telephone.

In the present invention the gain of speaker **104** is automatically adjusted manner similar to the microphone gain. The background noise level value calculated by background noise level detection unit **114** is applied to speaker gain look-up table **118** to read out a speaker gain value appropriate for the background noise level. An exemplary speaker gain look-up table is illustrated in FIG. 5. Speaker gain look-up table **118** has entries **130** for background noise levels and entries **132** for corresponding speaker gain values. The speaker gain values may represent voltage or current levels for controlling the gain of an amplifier (not separately shown) of the speaker. A default value may be employed for any noise levels not having an entry in speaker gain look-up table **118**. Also, as with microphone gain look-up table **116**, the speaker gain look-up table **118** may be accessed continuously or periodically, or perhaps only once per call or only at power-up.

However, unlike microphone gain look-up table **116** which is preferably programmed with values selected to decrease the gain with increasing noise levels, speaker gain look-up table **118** is preferably programmed with values selected to increase gain with increasing noise levels. The speaker gain values may, for example, be set to increase gain by an amount substantially proportional to an increase in background noise levels. As such, the user need not adjust the speaker gain by a manual control unit (not shown). Rather, automatic adjustment is performed.

What has been described are exemplary embodiments of a cellular telephone configured to automatically decrease microphone gain and increase speaker gain in response to an increase in background noise levels of the environment of the cellular telephone. In the exemplary embodiments, the decrease in microphone gain and the increase in speaker gain are both proportional to an increase in background noise levels. In other embodiments, other relationships between the microphone and speaker gains and the background noise levels are envisioned. In general, any desired relationship may be employed merely by pre-programming the look-up tables with appropriate values. The values may, for example, be initially calculated based upon a mathematical relationship such as simple proportionality. In other cases, appropriate values may be determined empirically by measuring the extent to which actual telephone user increases his or her speaking volume in response to changes in background noise levels. As can be appreciated, a wide range of possible techniques for

determining the appropriate values for storing in the look-up tables may be employed consistent with the general principles of the invention. Furthermore, look up tables are not necessary. Any suitable means for adjusting the microphone and speaker gains may be employed. For example, the detected noise level digital value may be converted to an analog voltage, processed by circuitry to scale and invert if necessary, then applied directly to respective amplifiers of the microphone and speaker for adjusting the gain.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

I CLAIM:

CLAIMS

1. In a mobile telephone, an improvement comprising:

means for generating a microphone gain adjustment of the telephone based upon a detected background noise level in the environment in which the telephone is operated; and

a microphone for receiving an acoustic signal and for amplifying the acoustic signal in accordance with said microphone gain adjustment.

2. An apparatus for adjusting the gain of a microphone of a mobile telephone, said apparatus comprising:

means for detecting the background noise level of the environment in which the mobile telephone is operating; and

means for setting the gain of the microphone of the mobile telephone based upon the detected background noise levels.

3. The apparatus of claim 2 wherein the means for setting the gain of the microphone operates to decrease the gain in response to an increase in background noise levels.

4. The apparatus of claim 2 wherein the means for setting the gain of the microphone operates to set the gain to a level inversely proportional to the background noise level.

5. The apparatus of claim 2 further including means for setting the gain of a speaker of the mobile telephone based upon the background noise level.

6. The apparatus of claim 5 wherein the means for setting the gain of the speaker of the mobile telephone operates to increase the gain of the speaker in response to an increase in the background noise level.

7. An apparatus for adjusting the gain of a microphone of a mobile telephone, said apparatus comprising:

a background noise detection unit;

a microphone gain control unit; and

an adjustment unit configured to adjust a gain of the microphone using the microphone gain control unit based on a background noise level detected by the background noise level detection unit.

8. The apparatus of claim 7 wherein the adjustment unit operates to decrease the gain in response to an increase in background noise levels.

9. The apparatus of claim 7 wherein the adjustment unit operates to set the gain of the microphone to a level inversely proportional to the background noise level.

10. The apparatus of claim 7 further including
a speaker;
a speaker gain control unit; and
wherein the adjustment unit also is configured to adjust the gain of a speaker of the telephone using the speaker gain control unit based on the detected background noise level.

11. The apparatus of claim 10 wherein the adjustment unit operates to increase the gain of the speaker in response to an increase in the background noise level.

12. The apparatus of claim 7 wherein the adjustment unit is a digital signal processor.

13. The apparatus of claim 12 wherein the digital signal processor unit includes a microphone gain lookup table.

14. A method for use in a mobile telephone comprising the steps of:
detecting the background noise level of the environment in which the mobile telephone is operating; and
setting the gain of a microphone of the mobile telephone based upon the detected background noise levels.

15. The method of claim 14 wherein the step of setting the gain of the microphone is performed to decrease the gain in response to an increase in background noise levels.

16. The method of claim 14 wherein the step of setting the gain of the microphone is performed to set the gain to a level inversely proportional to the background noise level.

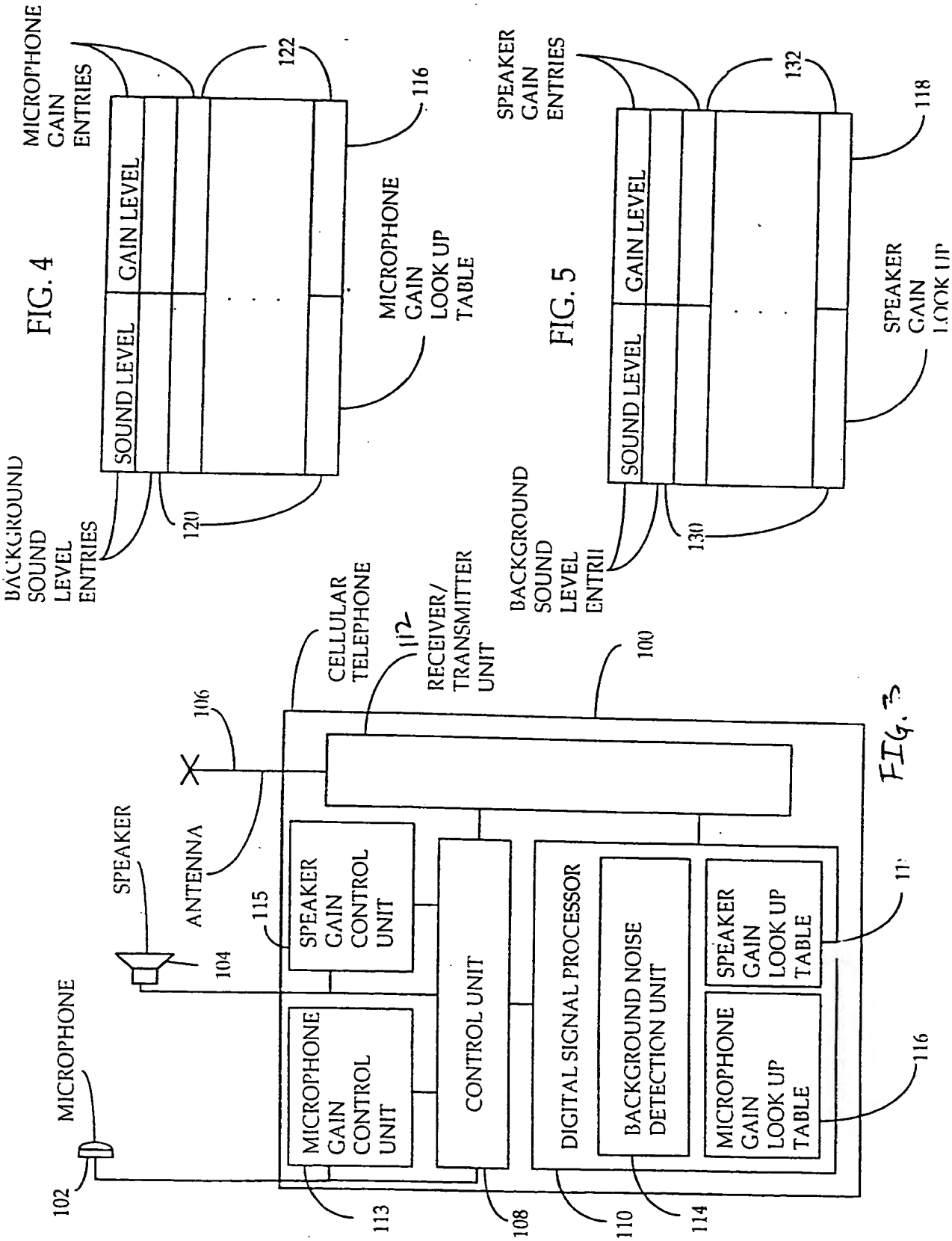
17. The method of claim 14 further including the step of setting the gain of a speaker of the mobile telephone based upon the background noise level.

18. The method of claim 17 wherein the step of setting the gain of the speaker of the mobile telephone is performed to increase the gain in response to an increase in the background noise level.

19. An apparatus for adjusting the gain of a speaker of a mobile telephone, said apparatus comprising:

means for detecting the background noise level of the environment in which the mobile telephone is operating; and

means for setting the gain of the speaker of the mobile telephone based upon the detected background noise levels.



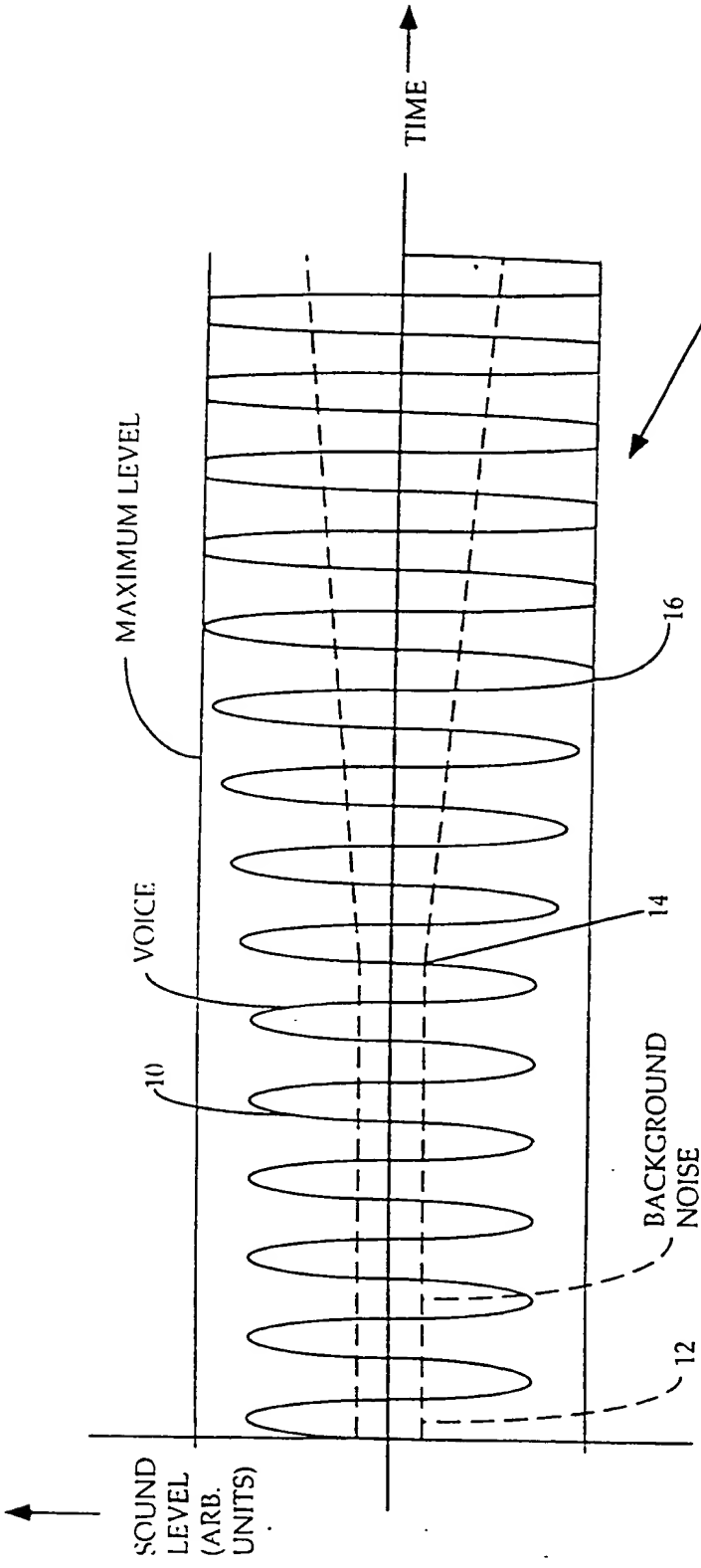

TIME
CLIPPING
MAXIMUM LEVEL
16
VOICE
14
10
BACKGROUND NOISE
12
SOUND LEVEL (ARB. UNITS)

FIG. 1

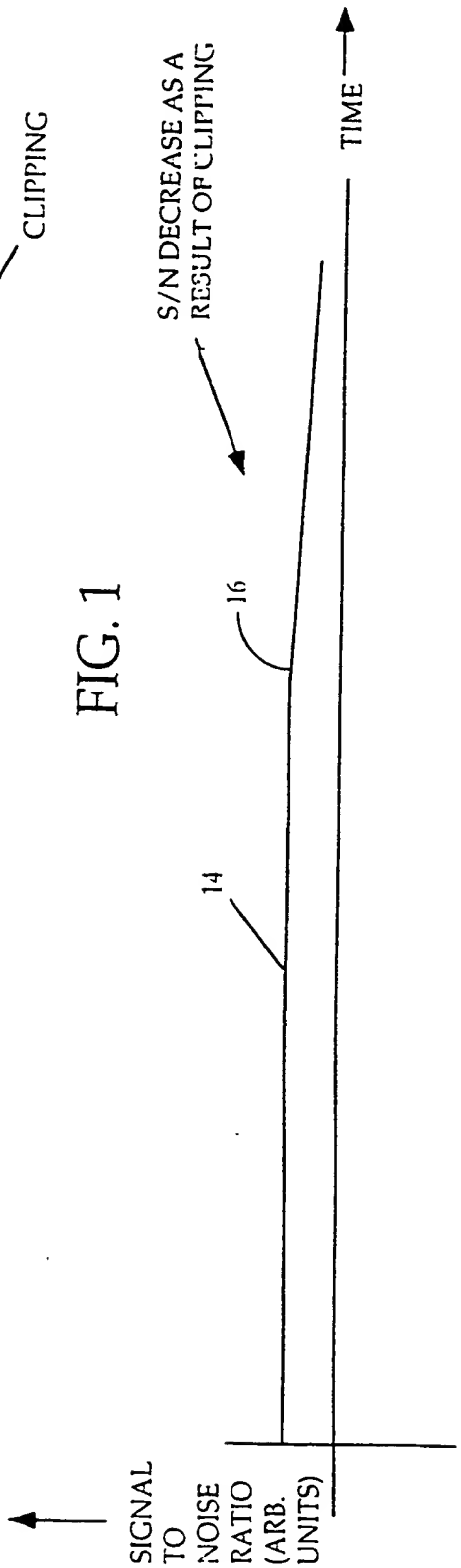

S/N DECREASE AS A RESULT OF CLIPPING
TIME
16
14
SIGNAL TO NOISE RATIO (ARB. UNITS)

FIG. 2

INTERNATIONAL SEARCH REPORT

Interna al Application No
PCT/US 97/13003

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04M1/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X Y A	US 3 889 059 A (THOMPSON JAMES LAWRENCE EARL ET AL) 10 June 1975 see column 1, line 19 - line 30 see column 1, line 43 - line 50 see column 2, line 17 - line 56 see column 4, line 65 - column 5, line 25 ---	1-4,7-9, 14-16 5,6, 10-13 5,6
X Y	US 4 829 565 A (GOLDBERG ROBERT M) 9 May 1989 see abstract --- -/--	19 5,6,10, 11

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
5 November 1997	18. 11. 97
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	**Authorized officer** Goulding, C

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INTERNATIONAL SEARCH REPORT

Interna al Application No
PCT/US 97/13003

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Internal Application No
PCT/US 97/13003

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